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The Wheat Stem Rust Epidemic of 1937 in Kansas

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THE WHEAT STEM RUST EPIDEMIC OF 1937 IN KANSAS[1/]

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After a lapse of only one year the winter wheat of the central United States again was damaged by a severe epidemic of stem rust (Puccinia graminis tritici). Two serious epidemics of that disease in a period of only three years is an unusual occurrence in the relatively dry area in which hard red winter wheat is grown. In 1937 very heavy losses resulted in Kansas from stem-rust infection in the eastern half of the State, and in some localities rust damage was greater than that recorded for the severe epidemic of 1935. Heavy local infections developed in north-central Texas late in May and moved gradually northward with the main path of infection directed northeast across eastern Oklahoma, southeastern Kansas, central Missouri, and central Illinois. Owing to the prevailing southerly winds, there was considerable spread of rust north of this main pathway and heavy infections developed on winter wheat in southeastern Nebraska and southwestern Iowa as well as on spring wheats farther north. Because of severe drought in western Kansas most of the surviving wheat acreage was in the eastern half of the State where rust was the most serious. Of the 158 million bushels of wheat produced in the State in 1937, more than 115 million bushels were grown in the eastern half in spite of rust.

Meteorologic Conditions Compared with Those Recorded for 1935

Weather conditions in Kansas during May and June were somewhat similar to those for the same months in 1935 but different from them in certain respects. Inasmuch as the drought during the winter and early spring had seriously damaged the wheat crop in the western third of the State before the stem-rust epidemic developed, the remarks on meteorologic factors will be confined mostly to the central and eastern thirds of the State. Severe

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[1/] Contribution No. 378 from the Department of Botany, Kansas Agricultural Experiment Station, in cooperation with the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.

drought continued in much of the western third throughout the spring months and except for localities favored by local rains the wheat crop was seriously damaged in that section by lack of moisture. Although some stem-rust infection appeared in western counties, it usually was light and its effect was overshadowed by drought injury.

Surveys and information from other sources revealed that stem rust made its appearance in the southern counties, from Harper County eastward during the last few days of May. Infection spread gradually northward and reached its peak by June 20 in the eastern two-thirds of the State. Assuming that temperatures and rainfall occurring more than two weeks before the appearance of stem-rust infection could have had little effect on the development of the epidemic, it appears that meteorologic conditions which most critically affected rust development must have occurred during the period May 15 to June 15, inclusive. By June 20 the maximum daily temperatures had risen above 100° F., rust infection was arrested in its development, and the wheat crop matured very rapidly.

The rainfall during May and June in 1937 followed the same general trend as that for the same months in 1935 but was much lighter. Figures 1 and 2[2/] show that there were frequent rains at Manhattan during the last two weeks of May and the first two weeks of June in both years. When the total amount of rainfall for May and June in both years is compared, however, it is apparent that there was a great excess of moisture in the eastern two-thirds of Kansas in May, 1935 and a moderate excess in both sections in June (Table 1). In 1937 the rainfall was below normal in all cases except for a very slight excess in the central section in May. Thus,

Table 1. Average rainfall, mean temperatures, and departure from normal in the eastern and central thirds of Kansas in 1935 and 1937.

Month	Section of State	Rainfall in inches: Average 1935	Average 1937	Departure 1935	Departure 1937	Mean temperature in degrees F.: Average 1935	Average 1937	Departure 1935	Departure 1937
May	Eastern	10.22	4.06	+5.37	-0.77	60.4	66.8	-4.1	+2.1
	Central	8.46	3.96	+4.64	+0.12	60.0	67.3	-4.1	+3.0
June	Eastern	7.30	3.59	+2.40	-1.22	70.6	75.2	-3.6	+0.9
	Central	5.05	3.18	+0.91	-0.88	71.1	75.1	-3.2	+0.7

it would seem that a heavy stem-rust infection developed under excess-moisture conditions in 1935 and under moisture-deficient conditions in 1937. The writers are of the opinion that the total rainfall is of less importance in the development of stem rust than the frequency and distribution of rains and other forms of moisture, other conditions being equal.

2/Figures at end of Supplement.

Thus, while the rainfall in May and June, 1937, was generally below that in 1935, Figure 1 shows that precipitation in some form occurred on all but 7 days of the critical infection-rust period of May 15 to June 15. During that period rain fell on 17 of the 32 days, and moisture in the form of fog, mist, or dew occurred on 8 other days. On several occasions there were both dew and showers in single 24-hour periods. Except for June 12, on which a very strong wind blew from the south, there was some form of precipitation on each of the first 15 days, although the total for the period was only 3.37 inches. Owing to the frequency of occurrence, moisture conditions seemed to be nearly ideal for stem-rust infection at Manhattan. Similar conditions throughout the eastern two-thirds of the State were reported in Climatological Data of the U. S. Weather Bureau. However, in the southeastern part, where the heaviest stem-rust infection occurred, there was considerably more rain than in other parts of Kansas, and, during the period June 8 to 15, inclusive, many fields were waterlogged. Moreover, because of favorable growing conditions in that section, growth of wheat was very rank and there was much lodging.

A comparison of the temperature charts for 1935 and 1937 (Figs. 1 and 2) reveals certain general similarities. The mean temperatures were higher in both the eastern and central sections in 1937 than in 1935. Thus it seems that a heavy epidemic developed in the presence of subnormal temperatures in 1935 and supernormal temperatures in 1937. However, the excesses recorded for 1937 were so slight that the influence on stem-rust infection probably differed little from the normal season. It is conceivable that the slightly higher average temperatures favored rather than reduced infection. The mean May temperature for the State was 59.0° F. in 1935 and 66.7° F. in 1937. The mean temperature for June was 71.0° F. in 1935 and 74.3° F. in 1937.

Although mean temperatures as well as maxima and minima doubtless are important contributing factors in the development of any stem-rust epidemic, the writers are of the opinion that minimum temperatures are the most important of the three measurements. Not until minimum temperatures become high enough to favor abundant germination of urediospores have heavy stem-rust infections been noted in Kansas. Minimum temperatures usually are those recorded at night and it should be noted that most of the spring rains and all of the dews occur at night or in the very early morning. It would seem, therefore, that conditions particularly favorable for stem-rust infection would be the occurrence of some form of free moisture in the presence of relatively high minimum temperatures. Figure 2 shows at least 3 periods when moisture and temperature conditions were very favorable for rust infection during May and June, 1935. Figure 1 shows three similar periods between May 15 and June 20, 1937. It is interesting to note the close coincidence of the dates of the two last favorable periods in 1937 with similar periods in 1935. A rather long period began on May 24 and extended to June 4, 1937. A similar period occurred from May 26 to June 3, 1935. The second favorable

period extended from June 11 to June 16 in 1937, and a similar period was recorded from June 11 to June 17, 1935. It should not be inferred that infection occurred only on dates included in the periods recorded as favorable. Some infection undoubtedly did occur on other dates, but it is believed that conditions on the dates indicated were particularly favorable for stem-rust infection and that the occurrence of such favorable periods plays a major part in the development of epidemics. Some observers believe that the maximum temperatures on May 20, 28, and 29, and on June 12 and 13, 1937, were too high to favor the development of stem rust. However, they are day-time temperatures and had little, if anything, to do with infection. The temperature of 93° F. on May 20 and 28 may have retarded rust development a day, but it is doubtful if other maximum temperatures were high enough to have any retarding effect.

Crop Conditions in Relation to the Epidemic

A survey of crop conditions in the spring of 1935 indicated that the stem-rust epidemic of that year was favored in its development by late heading and a very long fruiting period induced by subnormal temperatures in combination with heavy rainfall. Delayed heading in 1935 was due to prolonged winter and early spring drought. In 1937 the development of the crop in the eastern two-thirds of Kansas was only slightly delayed by early spring drought; heading, therefore, was earlier than in 1935. Light but frequent rains during the last two weeks of May and first two weeks of June favored top growth and in parts of the State (Section IV, Figure 3), the wheat was very rank and succulent. Much lodging occurred in some varieties in that section. Rank growth naturally favored the development of stem rust and was an important factor in the heavy infections of that area. In section III also, top growth was abundant in most fields but not so heavy as in section IV. In all sections the temperatures were sufficiently high to permit the normal development of the crop to a point where it was able to mature very rapidly when the temperatures rose to 100° F. or higher on June 20. Temperatures remained very high for a week following that date and most wheat ripened in that period.

Another interesting feature of the 1937 wheat crop in Kansas was the large acreage in part of the western half of the State, where the plants were severely injured by drought prior to normal heading time, but recovered to some extent after the rains began in May. Plants in this area put out many fresh green tillers after the first of June. The area in which this situation developed is shown in Figure 4. In several of the affected counties, notably Saline, Ellsworth, Barton, Russell, and Ellis, considerable stem-rust infection had developed on the late, green tillers by June 15. High temperatures beginning about June 18 so injured the secondary growth that most of it soon died; many damaged fields were plowed up by June 25. Had the season remained cool enough to permit the

new tillers to continue their development, they probably would have been destroyed by stem rust. The high temperatures not only killed the plants but also arrested development of stem rust and prevented the building up of inoculum for northward distribution.

Source of Stem Rust Inoculum and Progress of the Epidemic

The writers have no evidence indicating that stem rust in the uredial stage overwintered in Kansas in any significant quantity in 1937. It cannot be said that no overwintering occurred, but the lateness of the appearance of stem rust in the spring indicates that overwintering was not abundant. The first reports of the presence of stem rust in the State were received from Sumner and Cowley Counties, along the southern border, on May 26. On May 16 an examination of several fields of wheat in Sumner County had revealed no infection, but traces of primary infection were found about 50 miles south of the Kansas line near Perry, Oklahoma. Light to moderate infections were observed the following day in southern Oklahoma and a rather heavy local infection was encountered at Denton in northern Texas. No stem rust was observed on winter wheat in the vicinity of Manhattan until June 4, but infections found on that date undoubtedly had been present for 3 or 4 days. By this time, reports of heavy infection were being received from counties along the southern border of the State from Harper County eastward, with indications of a very heavy concentration in the southeastern part. By June 8 light to moderate infection could be found in nearly every field of wheat as far north as the central part of the State, and the rust was approaching epidemic proportions in the southern counties. One particularly striking feature of the development of stem rust in Kansas in the early part of the season was the unusually heavy infection on the leaves. On a survey made on June 9 and 10, fields were frequently encountered in which leaves exhibited as high as 25 percent infection, while stems showed only a trace to 5 percent.

As soon as it became obvious that heavy stem-rust infection was likely to occur in eastern Kansas, the writers made frequent survey trips in the affected area to gain first-hand information on the progress and extent of the epidemic. The situation was so serious and was changing so rapidly that aid in making a thorough survey was asked of several Federal and State officials then known to be traveling in the State. Invaluable aid was furnished by Wallace Butler, of the Bureau of Entomology and Plant Quarantine, and by K. S. Quisenberry, C. H. Ficke, and A. G. Johnson, of the Bureau of Plant Industry, United States Department of Agriculture. Equally valuable assistance was given by John H. Parker, of the Kansas Agricultural Experiment Station. Figure 5 shows the routes of survey trips originating or terminating at Manhattan during the period of May 16 to June 25, inclusive. Nearly every county in the eastern half of the State was entered at least once and many counties were visited several

times. By June 25 reports on 238 field observations had been received from all of these sources and an excellent picture of the extent and severity of the epidemic was beginning to take form.

Besides the survey just discussed, information and opinions also were sought from capable observers in various localities to assist in the measurement and evaluation of the infection. Reports were received from farmers, millers, elevator operators, county agents, branch experiment station personnel, crop inspectors, estimators, reporters, and many others whose experience with wheat in Kansas lent weight to their opinions.

All surveys and other sources of information agreed by June 15 that a major epidemic of stem rust was certain to occur in the eastern third of the State. By that date nearly every field of winter wheat in the eastern two-thirds of the State contained more or less stem-rust infection. The situation rapidly became more critical and the epidemic reached its peak in eastern Kansas by June 20 after which further infection was prevented by extremely high temperatures which began on June 18. Wheat matured very rapidly after the latter date in all except occasional late fields. The heavy crop in the central part of the State, therefore, escaped much of the severe loss experienced farther east.

Full information on the physiologic races of stem rust involved in the 1937 epidemic in Kansas is not yet available, but the writers are grateful to Dr. E. C. Stakman, of the University of Minnesota, for the advance information that physiologic races 11 and 56 were two of the most important ones. Race 56 was the most abundant one in 1935 and its recurrence in abundance in 1937 indicates that it is now an important one in the western plains area.

Distribution, Prevalence, and Severity of Stem Rust

These topics already have been partially discussed above but certain phases need further emphasis. By harvest time stem rust of wheat was present throughout Kansas. Even the drought-injured crop in the extreme western part of the State had traces of stem-rust infection. The amount of infection increased regularly from west to east, with the heaviest infections occurring in the eastern 4 ranges of counties. The data on losses shown in Figure 3 are a fair indication of the severity of infection but do not reveal the whole picture. For example, the average loss for section III was only 3.51 percent, but a great many fields in that section had 60 to 80 percent infection. The highest average yields in the State were obtained in section II, although most fields had considerable stem rust. In both of these sections wheat was well advanced before heavy rust infection developed and harvest was not delayed by wet weather as it was in the eastern counties. The crop, therefore, was in the right condition to mature rapidly and produce high yields

when the hot weather began on June 18. In section IV infection was extremely heavy, susceptible varieties exhibiting 100 percent infection in nearly every field. It is doubtful if there was a single field of winter wheat in the eastern two-thirds of Kansas that did not have considerable stem-rust infection by harvest time and at least traces could be found in almost every field in the western third of the State.

Magnitude and Types of Losses

Four main types of loss caused by stem rust were noted in 1937 and are discussed below under appropriate headings.

1. Reduction in yield. The percentage loss in each county in eastern Kansas (Fig. 3) is an estimated average made after comparing the estimates of several competent observers with the writers' knowledge of the situation and with market reports and information furnished by the Kansas State Board of Agriculture. The records of the surveys discussed above were compared with estimates on losses made by county agricultural agents, Federal officials, and others familiar with the situation. The percentages shown in Figure 3, therefore, represent the composite opinion of several separate observers and should be as accurate as any estimate could be expected to be.

The lines dividing the State into 4 sections are partly natural on the basis of the percentage loss and partly arbitrary to provide a fairly straight north and south arrangement. For example, there are several counties in section IV having much lower percentage losses than surrounding counties in that section. The amount of rust infection in such counties as Wabaunsee, Shawnee, Douglas, Osage, Coffey, and Chautauqua suggests that the estimates of loss should have been higher, but the figures shown were the most reliable ones obtainable.

The percentage loss figures given in Figure 3 show more clearly than the bushel loss that the greatest rust damage was roughly in the four eastern ranges of counties, with the heaviest concentrations in southeastern and northeastern counties. Section III was one in which stem-rust infection was generally heavy but where only moderate damage occurred. In section II, rust infection was generally moderate and the average loss was estimated at only 0.95 percent. The average loss from stem rust in section I was not over a trace, although there were localities where infection was heavy. Obviously some loss in yield resulted, even though it was small. Therefore, it was decided to evaluate all recorded traces as 0.2 percent in calculating the loss in terms of bushels.

The lower figures shown in each county of the eastern half of Kansas represent the calculated loss in bushels. This figure was obtained by using the estimated percentage loss with the estimated yields per county

as furnished by the Kansas State Board of Agriculture in its report of August 10. The August estimate is considered to be the most accurate one available until the final report is made after the entire crop is marketed or accounted for. The august report indicated a winter wheat yield for the State of 158,040,000 bushels. The bushels loss shown in Figure 3 also emphasize the heavy concentration of stem rust in southeastern and northeastern counties. The highest total loss in bushels was obtained in Brown County which also had the highest estimated percentage loss. Atchison County had the second highest loss in bushels, while Jackson County was in third place. These facts would seem to be at variance with the statement that the heaviest losses occurred in southeastern counties, but it is the consensus of opinion among capable observers that the most widespread serious losses occurred in southeastern Kansas. The large loss in bushels in some of the counties in section IV was based on a high estimated percentage loss and an unusually large acreage of wheat in those counties.

Table 2. Losses caused by stem rust and yield of winter wheat in four sections of Kansas in 1937.

Section of State	Ave. percent loss	Loss in bushels	Actual yield in bushels	Potential yield in bushels
I	Trace	90,695	45,257,000	45,347,695
II	0.95	461,620	48,155,000	48,616,620
III	3.51	1,458,010	40,039,000	41,497,010
IV	27.14	9,161,140	24,589,000	33,750,140
Average or total	6.60	11,171,465	158,040,000	169,211,465

The information given in Figure 3 is summarized in Table 2. It will be noted that the average loss from stem rust for the entire State was 6.60 percent and that the total loss was more than 11,000,000 bushels. At 90 cents a bushel, this represents a monetary loss of slightly more than 10 million dollars.

2. Losses from reduction in grade. This factor, while very real in nature, is extremely difficult to evaluate. It undoubtedly was included by most observers in their estimates on percentage loss and, therefore, is at least partially accounted for in the losses discussed above. It is certain, however, that much of the wheat harvested in section IV was badly shriveled, for many reports have been received showing test weights as low as 42 to 45 pounds per bushel. Much wheat was given a market grade of "sample" with the statement that it was fit only for feed.

After considering all of the figures and opinions available, it seems reasonable and safe to estimate the loss due to reduction in grade at about one-sixth of the monetary loss, or roughly about $1,500,000.

3. Abandonment. This type of loss also is extremely difficult to measure, although one of the writers saw some excellent examples of it in 1937. In the southeastern and northeastern parts of section IV, many fields of wheat were not harvested. In some cases farmers took combines into the field and cut a round or two but failed to obtain enough grain to pay them to continue. Many such fields were burned.

4. Losses from the necessity of procuring new seed. Most of the farmers in Kansas save a portion of their wheat crop for seed the following year or procure seed from their neighbors. In 1937 some farmers in the extreme eastern part of the State harvested no wheat because of stem-rust infection; many others harvested grain of such poor quality that it was not considered suitable for seed. Therefore, it was necessary for many farmers to buy new seed--sometimes at rather distant points and at prices somewhat above market price. Such losses cannot be accurately measured, although it is known that they were considerable in Kansas in 1937.

Reaction of Principal Commercial Wheat Varieties to Stem Rust in 1937

Some very wide differences in the response of commercial varieties to stem-rust infection were noted in 1937. In general, the soft red winter varieties were more heavily infected than the hard red winter sorts. The high susceptibility of the soft varieties partially accounts for the severe losses in the extreme eastern part of the State, for in that section much of the wheat grown is soft red winter. An opportunity was afforded to make stem-rust readings on varieties of wheat grown by the Department of Agronomy of the Kansas Agricultural Experiment Station in 52 cooperative tests with farmers in different parts of the State. A summary of the data obtained is presented in Table 3. It will be noted that Early Blackhull had the lowest average percentage infection and that Quivira was second lowest. Except for a single test of Early Blackhull in northeastern Kansas both of these varieties were tested only in the central and western sections of the State, where infection was not so heavy as farther east. Furthermore, both varieties are very early and tend to escape heavy infection. Rust records of these varieties compared with Kanred and Oro in date of sowing experiments at Manhattan revealed, even in late sowings, that Early Blackhull had an average of 25 percent infection, Quivira 50 percent, and Kanred and Oro 60 percent each. Thus, it seems that in addition to its rust-escaping qualities because of earliness, Early Blackhull also has some resistance to stem rust.

Table 3. Percentage of stem rust on winter wheat varieties grown in cooperative wheat variety tests in Kansas, 1937

Variety	Weighted average percent stem-rust infection in sections of Kansas				Weighted average for State
	Northeast	Southeast	Southcentral	West and Northcentral	
Kanred	50(1)*	52(2)	31(15)	8(14)	22(32)
Turkey	74(9)	73(13)	36(15)	16(14)	47(51)
Tenmarq	78(9)	66(13)	31(15)	13(14)	44(51)
Cheyenne			37(11)	7(12)	21(23)
Blackhull	61(9)	56(14)	28(15)	8(14)	37(52)
Quivira			13(10)	1(3)	10(13)
Kanred x Hard Federation Ks 2673			32(10)	11(3)	27(13)
Early Blackhull	23(1)		4(11)	1(12)	3(24)
Kawvale	61(9)	49(13)	44(4)	48(2)	52(28)
Fulcaster	92(9)	87(14)	79(4)	78(2)	87(29)
Clarkan	86(9)	85(14)	74(4)	80(2)	80(29)
Harvest Queen	87(9)	83(14)	76(4)	73(2)	83(29)
Michigan Wonder	92(9)	83(11)			88(20)
Iobred	62(8)				62(8)
Chiefkan	85(1)		28(8)	27(6)	33(15)
Weighted average severity for section	75	72	32	15	

* Number in parentheses indicates the number of tests.

Table 3 shows clearly that stem-rust infection was heaviest in the northeastern and southeastern parts of the State, while it was only about one-half as severe in the south-central part and one-fifth as heavy in the north-central and western sections. It is notable, however, that the soft red winter varieties such as Fulcaster, Clarkan, Harvest Queen, and Michigan Wonder were heavily rusted in all sections.

In northeastern Kansas, Early Blackhull had the lowest percentage infection, but the variety appeared in only one test. It was followed in order by Kanred, Blackhull, Kawvale, and Iobred. Kanred and Blackhull are not recommended for that section of the State for agronomic reasons. Kawvale and Iobred were outstanding in that section for their ability to produce a crop in the presence of a heavy epidemic of stem rust. Both varieties are only moderately resistant and frequently may have rather heavy infections. Both are a little earlier than the soft wheats grown in that section and often partially escape infection. Both also have a type of resistance characterized by late initial infection and small uredia as well as relatively low percentages of infection. Iobred is grown only in a few counties in the extreme northeastern corner of the State.

Kawvale, on the other hand, is widely grown in the eastern third of Kansas. It made a remarkable record in the rust year 1935 and again in 1937. In both years it consistently made good yields in eastern Kansas in localities where nearby fields of soft wheats were destroyed by stem rust. Although Kawvale is a semihard wheat and is inclined to shatter when fully ripe, it has several characteristics that permit it to make a crop in rust years. Besides the qualities mentioned above, Kawvale has a strong straw and, therefore, does not lodge easily. It also ripens rapidly, once it has turned. The combination of all of the foregoing favorable characters enables Kawvale to emerge with excellent yield records, even though it may show heavy stem-rust infection late in the season.

Among the wide-grown hard red winter wheats, Early Blackhull, Kanred, and Blackhull had the lowest average infections. Table 3 shows Cheyenne with a lower average infection than either Kanred or Blackhull, but it was grown only in the south-central, north-central, and western sections, where stem rust was lighter than it was in the eastern part of the State. Cheyenne is known to be a very susceptible variety. Early Blackhull is commercially grown principally in south-central Kansas, while Kanred is especially important in northwestern Kansas. Blackhull is now the most wide-grown variety in Kansas, and its moderate resistance to stem rust is of considerable importance. It possess some of the characteristics that already have been discussed for Kawvale. Besides a moderate degree of resistance, Blackhull also yields well, even under

conditions of occasional heavy infections. Under general field conditions it seldom shows as high percentages of infection as Turkey or Cheyenne, and the uredia usually are much smaller than those on fully susceptible varieties.

The average infection for Tenmarq (Table 3) indicates that it has about the same susceptibility to stem rust as Turkey. In the northeastern section, Tenmarq had a higher average percentage than Turkey, while in the south-central section, for which Tenmarq is recommended, it was slightly less severely rusted than Turkey and very similar to Kanred in its behavior.

Although Iobred, Kawvale, Early Blackhull, Blackhull, and Kanred are recognized as possessing some resistance to stem rust, none of them has the degree of resistance desired and a program of breeding for stem-rust resistance is under way at Manhattan. None of the winter wheat varieties tested proved to have strong enough resistance to stem rust, so it was necessary to use such spring wheats as Hope, Marquillo, Thatcher, and Renown as sources of resistance in crosses. Numerous winter-wheat segregates having high resistance to stem rust have been isolated and purified. Some of the hybrid lines are sufficiently advanced to be grown in nursery yield-test experiments in 1938, and it is hoped that within a few years both hard and soft red winter wheats, highly resistant to stem rust, will be available for distribution.

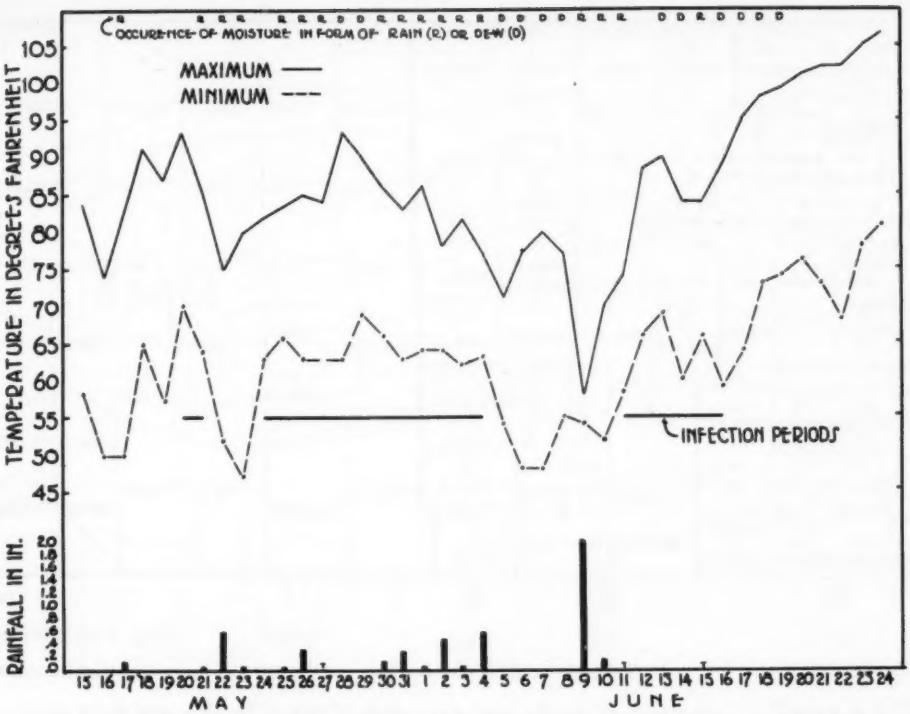


Figure 1: Maximum and minimum air temperature, rainfall, and periods favorable to the development of stem rust at Manhattan, Kansas, from May 15 to June 24, 1937

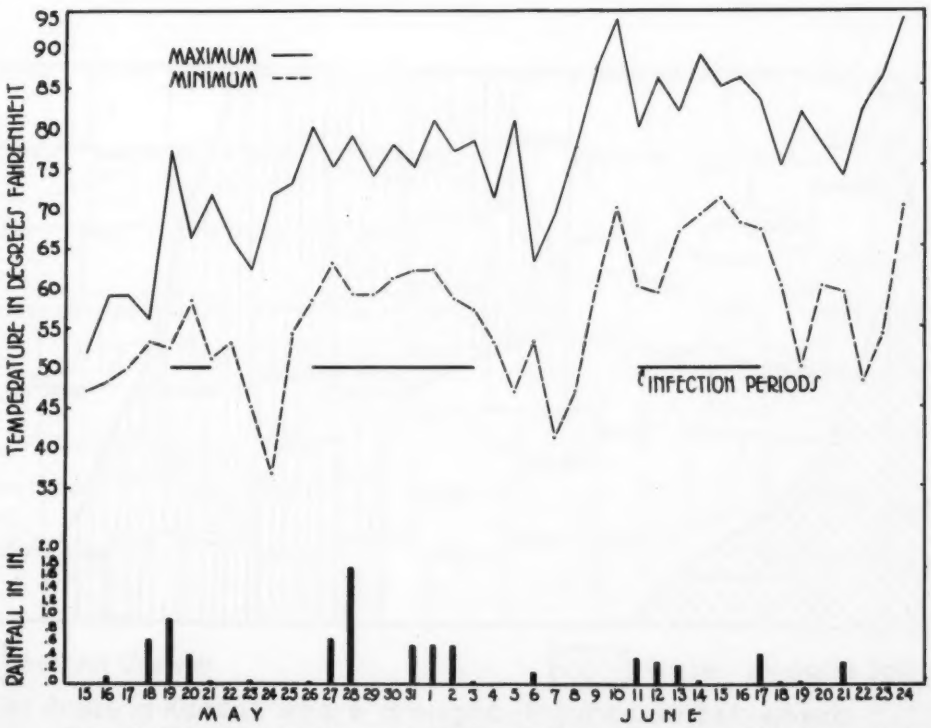
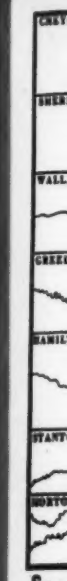


Figure 2: Maximum and minumum air temperatures, rainfall, and periods favorable to the development of stem rust at Manhattan, Kansas, from May 15 to June 24, 1935



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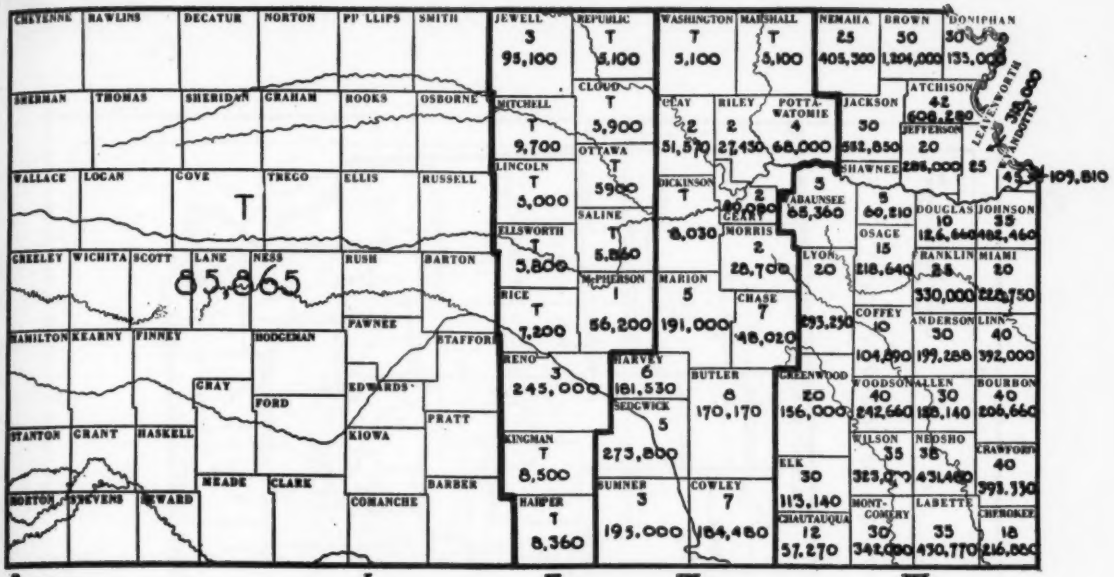

Section	I	II	III	IV
Average percent loss	Trace	.95	3.51	27.14
Loss in bushels	90,695	461,620	1,458,010	9,161,140

Note: upper number = % of loss; lower number = loss in bushels: — Trace = .2%

Figure 3: Average percent loss and total loss in bushels due to stem rust infection on winter wheat in four sections of Kansas in 1937.

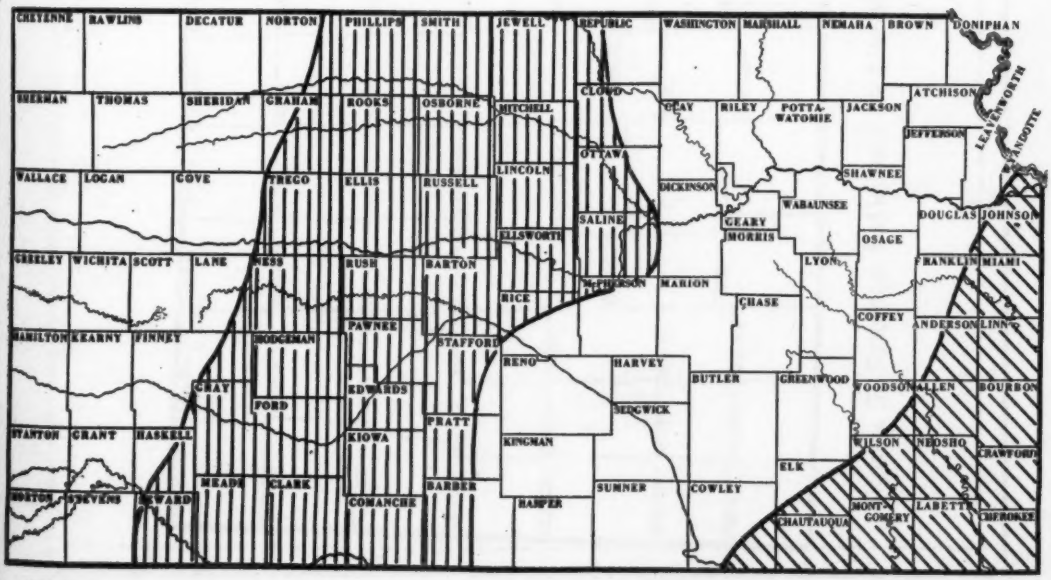
CHEYENNE RAWLINS DECATUR NORTON PHILLIPS SMITH JEWELL REPUBLIC WASHINGTON MARSHALL NEMAHA BROWN DONIPHAN
SHERMAN THOMAS SHERIDAN GRAHAM ROOKS OSBORNE MITCHELL CLOUD CLAY RILEY POTTAWATOMIE JACKSON ATCHISON
WALLACE LOGAN COVE TREGO ELLIS RUSSELL LINCOLN OTTAWA JEFFERSON LEAVENWORTH WYANDOTTE
DICKINSON SHAWNEE
GREELEY WICHITA SCOTT LANE NESS RUSH BARTON ELLSWORTH SALINE WABAUNSEE GEARY DOUGLAS JOHNSON
MORRIS OSAGE
MCPHERSON MARION LYON FRANKLIN MIAMI
HAMILTON KEARNY FINNEY HODGEMAN PAWNEE STAFFORD RICE CHASE COFFEY ANDERSON LINN
GRAY FORD EDWARDS RENO HARVEY BUTLER GREENWOOD WOODSON ALLEN BOURBON
SEDGWICK
STANTON GRANT HASKELL KIOWA PRATT KINGMAN WILSON NEOSHO CRAWFORD
ELK
MEADE CLARK SUMNER COWLEY
MORTON STEVENS SEWARD COMANCHE BARBER HARPER CHAUTAUQUA MONTGOMERY LABETTE CHEROKEE
Second Growth
Water Logged Soil

Figure 4: Areas in Kansas where drought-injured winter wheat made second growth after rains in early June, and where wheat fields were water logged in mid-June.

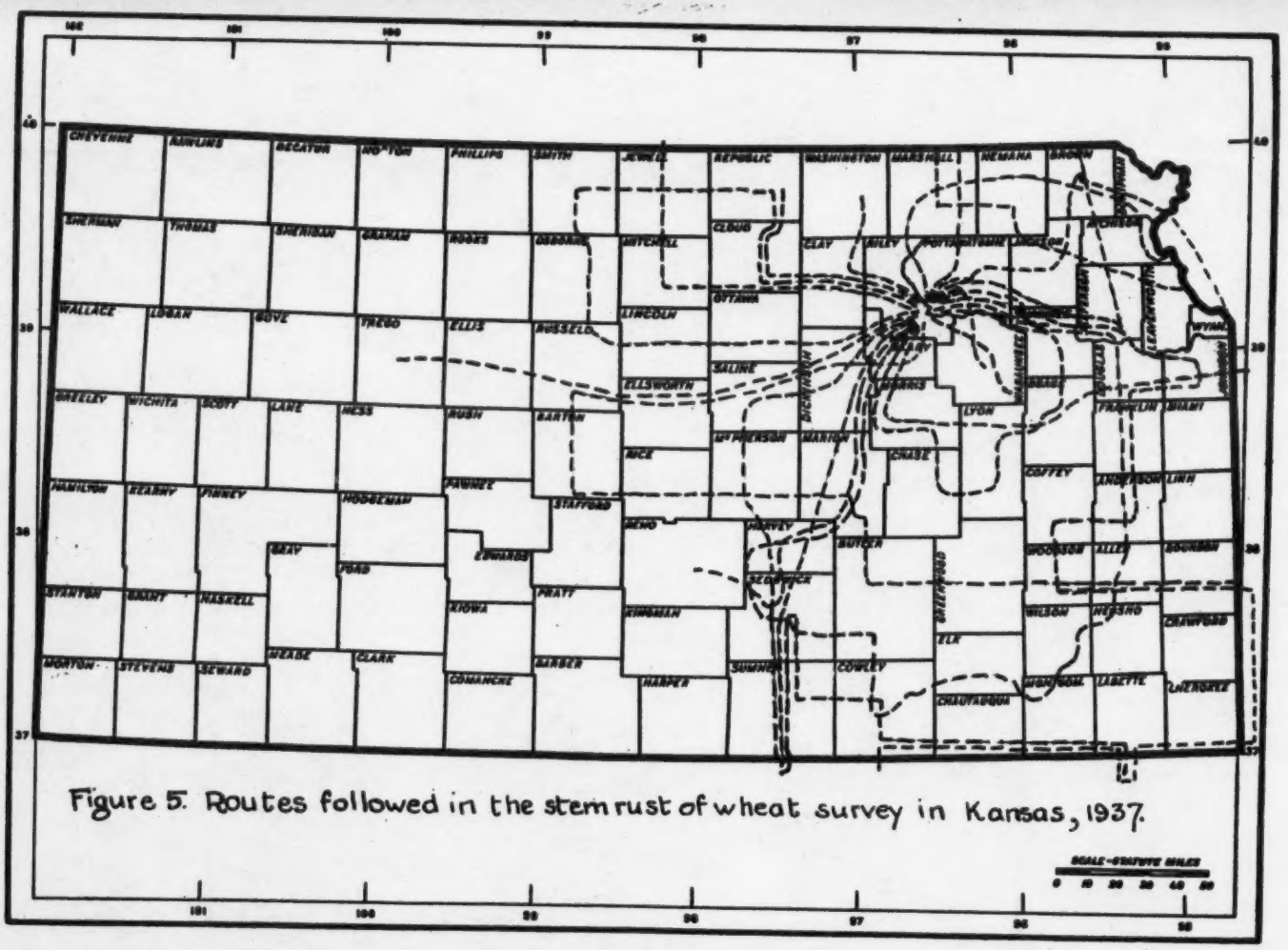
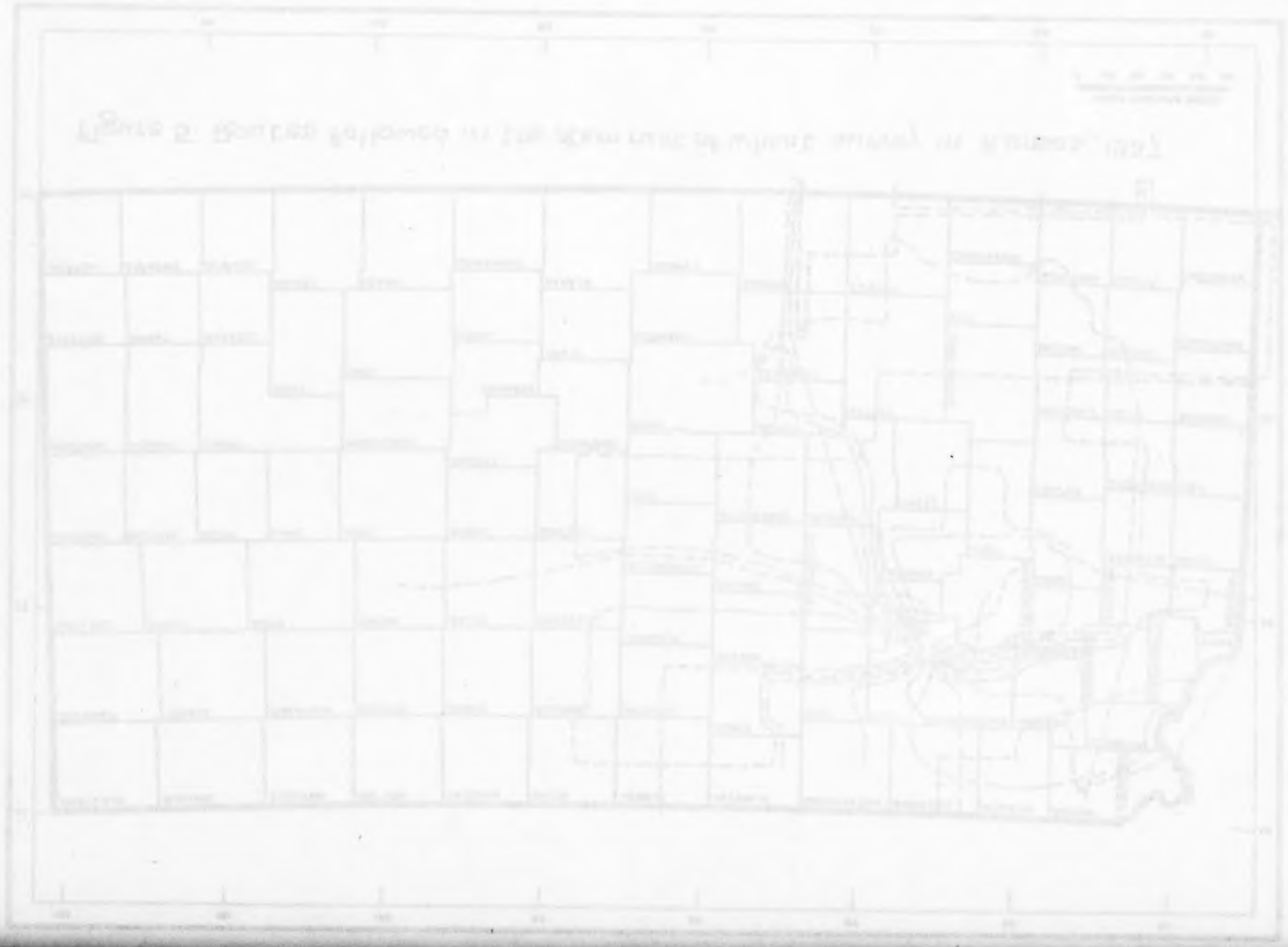
Figure 5. Routes followed in the stem rust of wheat survey in Kansas, 1937.